The image shows a spiral-bound notebook with a light brown, textured cover. The spiral binding is on the left side. The text is centered on the cover.

# **Artificial Intelligence**

## Natural Language Processing

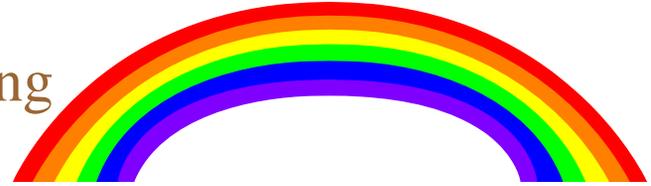
### **Lecture 10**

(3 November, 1999)

Tralvex (Rex) Yeap MAAI MSCS

University of London

# Content: Natural Language Processing



- 📄 Quick Review of Lecture 9
- 📄 Introduction to NLP
- 📄 NL and Computer Language
- 📄 Motivations for NLP
- 📄 NLP History
- 📄 Major NLP Accomplishments
- 📄 Real World NLP Applications
  - MT: Deluxe Universal Translator
  - IR: Buzzcity
  - IR: Altavista Search Engine
  - IV: Cartia's Themescape
  - Autonomous interacting bots: Eliza's grand-daughter - Lisa
  - Grammer Checking Systems: MS Word Grammer Checker

- 📄 A Generic NL System Architecture
- 📄 Language and Knowledge
- 📄 Five Processing Stages in a NLP System
  - (1) Phonological Analysis
  - (2) Morphological Analysis
  - (3) Syntactic Analysis
  - (4) Semantic Analysis
  - (5) Pragmatic Analysis
- 📄 Class Activity: Real-world Paper Reading
- 📄 Students' Mini Research Presentation by Group E
- 📄 What's in Store for Lecture 11

# Quick Review on Lecture 9



- 📄 Introduction to Planning
- 📄 Examples of Planning Systems
- 📄 Blocks World
- 📄 Assumptions of the "Standard" AI Planning Paradigm
- 📄 STRIPS - Linear Planner
- 📄 STRIPS Example
- 📄 State Space Searching
  - Progression Planners
  - Regression Planners
- 📄 Plan Space Searching
- 📄 Partial Ordered Planning
  - Introduction
  - An Example
  - Interpretation
- 📄 Partially ordered plans vs. Non-linear planning
- 📄 Shortcomings of AI Planning in General
- 📄 Class Activity: Real-world Paper Reading

# Introduction to NLP



- 📄 A **natural language** is a **human** spoken language, such as English.
- 📄 One of the **aims** of AI is to build machines that can "**understand**" commands in natural language, written or spoken.
- 📄 A computer that can do this requires very **powerful hardware** and **sophisticated software**.
- 📄 At the present time, this is at the **early stages** of development.

## Introduction to NLP (cont)



- It is **not an easy task** to **teach** a person or computer a **natural language**.
- The main problems are **syntax** (the rules governing the way in which words are arranged), and **understanding context** to determine the meaning of a word.
- To interpret even **simple phrases** requires a **vast** amount of **knowledge**.
- The basic goal of Natural language Processing is to **enable a person to communicate with a computer in a language** that they use in their **everyday life**.

# Natural Language and Computer Language



- ❏ **Natural language** are those that we use for communicating with each other, eg. **English, French, Japanese**, etc.
- ❏ Natural language are **expressive** and **easy** for **us** to use.
- ❏ **Computer languages** are those that we use for **controlling** the **operations** of a **computer**, eg. Prolog, C, C++, Java, etc.
- ❏ Computer languages are **easy** for a **computer** to understand, but they are **not expressive**.

# Motivations for NLP

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## **Traditional**

- Intellectual challenge for AI
- Easier human-computer dialogue

## **Recent**

- Information Revolution - Knowledge-Based Economy
- Information Highway, World Wide Web
- Globalization

# NLP History



## 1950-60: Machine Translation

- Georgetown University MT Experiment (1952-54): Crude models of mainly word-by-word translation with minimal syntactic analysis.



## 1960-70: Semantics-less

- String analysis models (1965) based on Chomsky's Transformational Grammar
- Natural Language Dialogue - ELIZA (Weizenbaum 1966): Keyword-based NL conversation

# NLP History (cont)



## 1970-80: AI takes the lead

- Development of NL-mediated “understanding systems”
- Augmented Transition Networks (Woods 1971) - A computationally feasible grammar formalism with the power of transformational grammar. Used for LUNAR (Woods 197?): System able to answer NL questions about moon rock samples.
- SHRDLU (Winograd 1971): NL dialogue with a simulated robot operating in a simple “blocks world”. System able to act and plan as well as answer questions.
- MARGIE (Schank 1973): NL understanding by making inferences based on conceptual knowledge.

## 1980-90: Grammar Formalisms

- Definite Clause Grammars (DCGs) - Parsing based on logic programming (Pereira and Warren 1980).
- Unication and Constraint Based Grammar
- Dialogue Systems Use of planning models for both understanding (Perrault and Cohen) and generation (Appelt 1985).

# NLP History (cont)



## **1990-Present: Integrated Language Engineering.**

- Statistical Methods - (1) Performance models (2) Highly empirical evaluation criteria.
- Multimodality - (1) Integration of Language and Speech (2) Large-scale language/speech projects.
- Multilinguality - (1) Multi Lingual Information Society (2) Machine Translation (3) Internationalisation of software (4) European Dimension.
- Language Resources - (1) Lexicons, Grammars (2) Text and speech corpora (3) Representation Standards

# Major NLP Accomplishments



- ☞ Chomsky (1957) **Syntactic Structures**
- ☞ Weizenbaum (1966), **ELIZA**
- ☞ Woods (1967), **Procedural semantics**
- ☞ Thorne et al. and Woods (1968-70), **ATNs**
- ☞ Winograd (1970), **Shrdlu**
- ☞ Colby, Weber & Hilf, 1971; Colby, 1975, **PARRY**
- ☞ Wilks (1972), **Preference semantics**
- ☞ Woods et al. (1972), **LSNLIS / Lunar**
- ☞ Charniak (1972), **Frames and demons**
- ☞ Wilks (1973), **Stanford machine translation project**
- ☞ Montague (1973) **IL semantics (Montague Grammar) in PTQ**
- ☞ Grosz (1977), **Focus in task-oriented dialogues**
- ☞ Marcus (1977), **Deterministic parsing**
- ☞ Davey (1978)
- ☞ Cohen, Phil (1979), **Planning speech acts**
- ☞ Allen (1980), **Understanding speech acts**
- ☞ McDonald (1980), **MUMBLE**
- ☞ Heim/Kamp (1981) **Discourse Representation Theory**
- ☞ McKeown (1982), **TEXT**
- ☞ Appelt (1982), **KAMP (Integration of Functional Grammar with Discourse Plans)**
- ☞ Shieber (1984) **Noncontextfreeness of NL syntax proven**
- ☞ Pollack (1986), **Plan inference**
- ☞ Mann & Thompson (1987), **Rhetorical Structure Theory**

# Real World NLP Applications



- Machine Translation
- Information Retrieval / NL interface
- Information Visualization
- Autonomous interacting bots
- Grammar Checking Systems
- Speech Recognition Systems / Speech Synthesizers
- Document Summary Systems

# Real World NLP Applications

## Machine Translation: Deluxe Universal Translator

The advertisement is set against a dark, starry background. On the left, a hand holds a globe with various national flags. The text 'Deluxe Universal Translator' is prominently displayed in a stylized font, with 'DELUXE' in large, metallic letters below it. The LanguageForce logo is at the bottom left. In the center, the word 'Omnidirectional' is written vertically. To its right, the word 'Translation' is written horizontally. Below this, a paragraph describes the technology: 'Universal Translator Deluxe™ provides you with a new breakthrough in machine-based translation technology: Omnidirectional translation. Rather than relying on English as an integral step for translating from one language to another (i.e., Japanese-to-English-to-Russian), our patent-pending artificial intelligence technology provides you with the ability to translate directly from one language to another!'. Below the text is a small globe with orbital lines. On the right, a box of 'Universal OCR' software is shown, with the text 'The Perfect Companion for your Universal Translator Deluxe' and 'Scan and Read 33 Languages with any Scanner!'. The LanguageForce logo and website URL are at the bottom right.

**Deluxe Universal Translator™**

**DELUXE**

LanguageForce

**Omnidirectional Translation**

Universal Translator Deluxe™ provides you with a new breakthrough in machine-based translation technology: Omnidirectional translation. Rather than relying on English as an integral step for translating from one language to another (i.e., Japanese-to-English-to-Russian), our patent-pending artificial intelligence technology provides you with the ability to translate directly from one language to another!

**The Perfect Companion for your Universal Translator Deluxe**

Scan and Read 33 Languages with any Scanner!

**Universal OCR**

World's Best Scanning Software

LanguageForce

Visit our web site at: [www.languageforce.com](http://www.languageforce.com)

Serial Number: A141720MN8P

- 📄 Able to translate text across 33 languages
- 📄 <http://www.languageforce.com/>

# Real World NLP Applications

## Information Retrieval: Buzzcity (<http://www.buzzcity.com>)

The screenshot shows a Netscape browser window displaying the BuzzCity website. The browser's title bar reads "BuzzCity Home: The Internet's Postman of Choice - Netscape". The address bar shows "http://www.buzzcity.com/". The website features a prominent banner for "www.boom.com" with a "Click Here" button. Below the banner, the site is titled "THE INTERNET'S POSTMAN OF CHOICE" and offers navigation links for "Worldwide", "Singapore", "HongKong-English", "HongKong-Chinese", "China (Preview)", and "Spain (Preview)". A search bar with the placeholder "enter email here" is followed by buttons for "Sign Up!", "Members' Login", and "Main Directory".

The main content area is divided into three columns:

- Producer's Picks:** Links to "SES Top 10 Gainers", "SES Top 10 Losers", and "SES Top 10 by Volume".
- Track any Topic:** A section for tracking topics, with an example "Test-ban Treaty" and a "Go!" button.
- Categories:** A list of categories including "Business & Finance", "Careers", "Entertainment", "Health & Leisure", and "News".

The central column contains a "What is" section with a blurred image and text describing BuzzCity as a "free" service that helps users use the Web more "efficiently" by updating them on happenings at "premium" sites. It promises to deliver the "freshest" information to the user's "email" and includes a link to "Tell me more". Below this is a "Don't miss these!" section with a bullet point: "Come check out NEW, hot and sizzling Hollywood gossip at BuzzCity!".

The right column features a "Members' Choice" section with a "What's this?" link and a list of items with checkboxes:

- Job Postings - JobSite Singapore
- World News - Channel NewsAsia
- Headlines - Business Times
- IT Jobs - ITWorks
- Professional/Executive Jobs - Singapore Job Bank
- Headlines - Financial Times

Automatically tracks/report user specify interest over Internet.

# Real World NLP Applications

## Information Retrieval: Altavista Search Engine

The screenshot shows the Altavista search engine interface. The search bar contains the query "what is natural language processing". Below the search bar, there are navigation tabs for "THE WEB", "NEWS", "DISCUSSION GROUPS", and "SHOPPING". The search results are displayed in a list format, with the first result being "1. What is Natural Language Processing:".

**1. What is Natural Language Processing:**  
What is Natural Language Processing: -An Introduction and Overview. Prepared By Louis Christian Stagner. A natural language is something that humans...  
**URL:** www.tredonia.edu/students/hix01903/papers/loulou.htm  
Last modified on: 11-Nov-1997 - 10K bytes - in English (Win-1252)  
[ Translate ] [ More pages from this site ]

The screenshot shows the Altavista search engine interface. The search bar contains the query "what is natural language processing". Below the search bar, there are navigation tabs for "THE WEB", "NEWS", "DISCUSSION GROUPS", and "SHOPPING". The search results are displayed in a list format, with the first result being "3. wextech.com - AnswerWorks - Natural Language processing for WinHelp and HTML H...".

**3. wextech.com - AnswerWorks - Natural Language processing for WinHelp and HTML H**  
WexTech Systems, the Help Experts. AnswerWorks - Natural Language processing for WinHelp and HTML Help. Tools for developing online Help (WinHelp,...  
**URL:** www.wextech.com/brawfaq.htm  
Last modified on: 15-Jul-1999 - 11K bytes - in English  
[ Translate ] [ More pages from this site ] [ Company factsheet ]

**4. Natural Language Processing & Information Retrieval (NLP/IR) Group Frequently A**  
Natural Language Processing & Information Retrieval (NLP/IR) How are works referenced? What is a monograph? What is a NIST Special Publication (SP)?...  
**URL:** www.nist.gov/dlrv/894/894.02/works/faq.html  
Last modified on: 8-Aug-1999 - 11K bytes - in English  
[ Translate ] [ More pages from this site ]

**5. Natural Language Processing of Medical Texts**  
Natural Language Processing of Medical Texts within the HELIOS Environment. Anne-Marie Rassinoux , Pierre-André Michel , Christian Juge, Robert Baud,...  
**URL:** mbi.dkfz-heidelberg.de/helios/doc/nlp/Rassinoux94c.html  
Last modified on: 8-Aug-1999 - 11K bytes - in English  
[ Translate ] [ More pages from this site ]

**6. Natural Language Processing**  
Natural Language Processing...  
**URL:** www.ai.uga.edu/~nakazawa/orais/node9.html  
Last modified on: 8-Aug-1999 - 11K bytes - in English  
[ Translate ] [ More pages from this site ] [ Company factsheet ]

**7. Natural Language Processing Module**  
Cognitive Studies/Psychology/Computer Science 201: COGNITIVE SCIENCE IN CONTEXT. Natural Language Processing Module (Part of Speech Tagging and...  
**URL:** www.csc.cornell.edu/201/natural\_language/index.html  
Last modified on: 21-Oct-1998 - 10K bytes - in English  
[ Translate ] [ Company factsheet ]

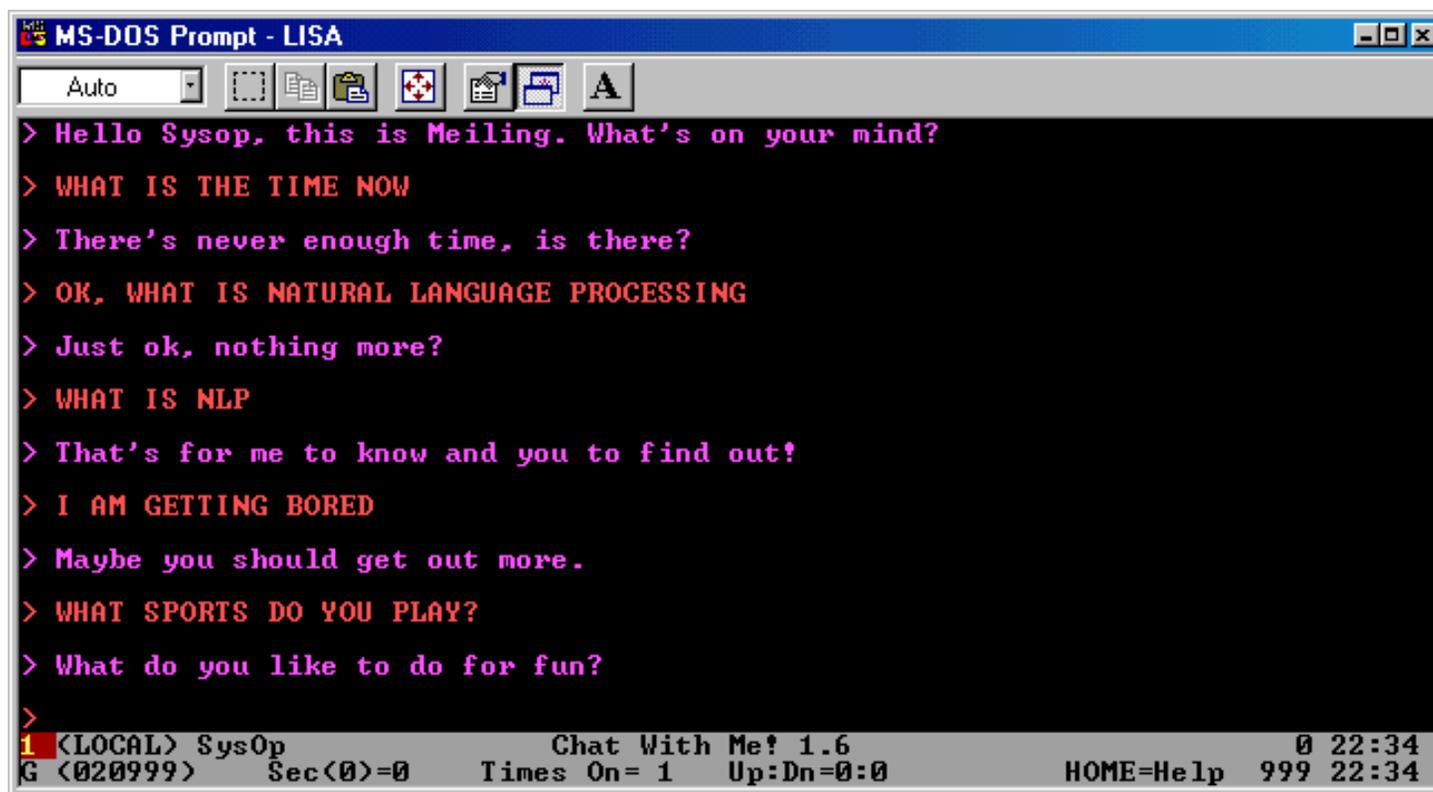
**8. Natural Language Processing**  
Natural Language Processing and Speech Recognition. Reference: Pigford and Baur pages 8, 170, Firebaugh Ch 8. What is Natural Language Processing...  
**URL:** busta.vut.edu.au/wenn/mbos/nlp/nlp.html  
Last modified on: 3-May-1999 - 10K bytes - in English  
[ Translate ] [ More pages from this site ]

Search engine supporting natural language query



# Real World NLP Applications

Autonomous interacting bots: Eliza's grand-daughter - Lisa



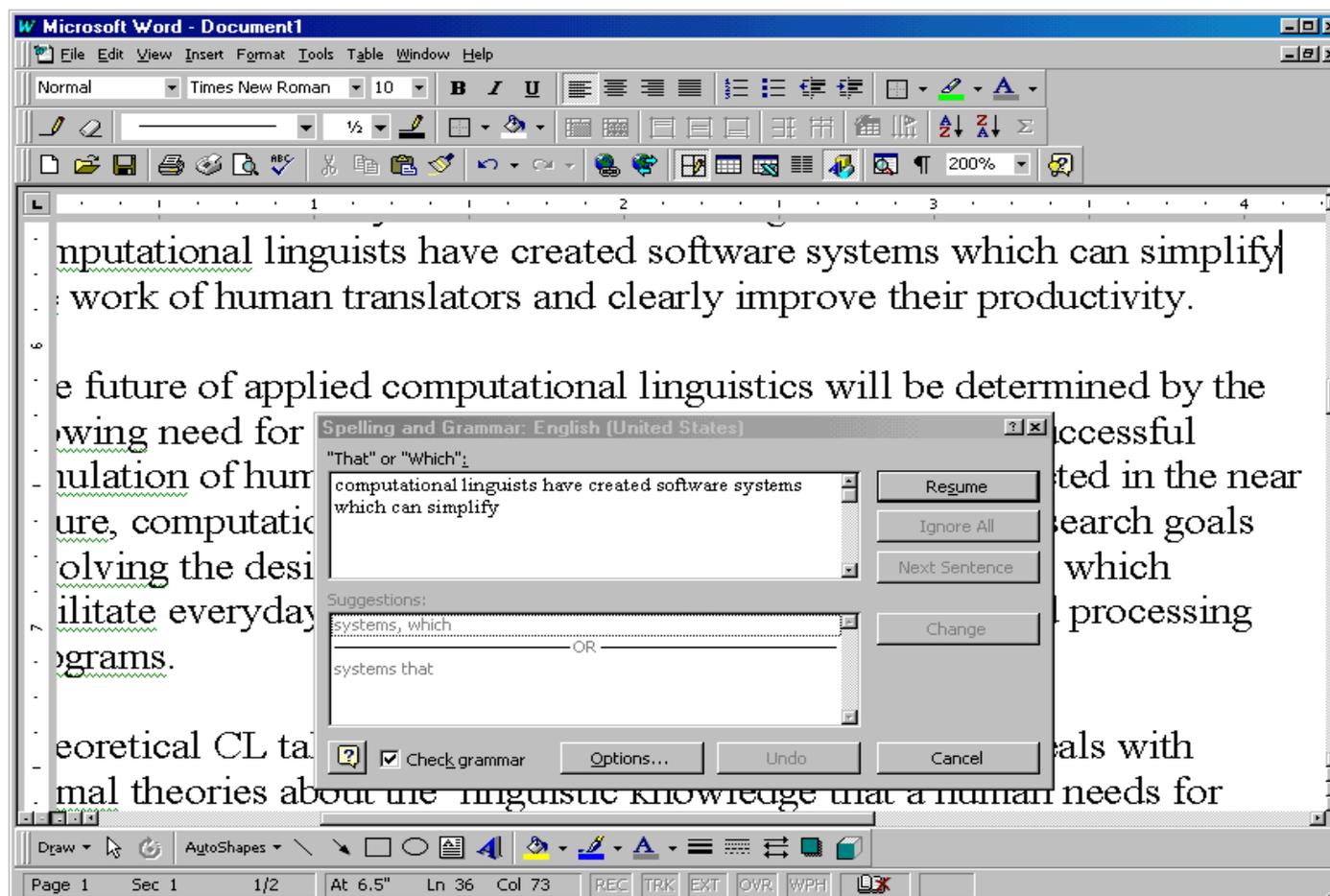
```
MS-DOS Prompt - LISA
Auto
> Hello Sysop, this is Meiling. What's on your mind?
> WHAT IS THE TIME NOW
> There's never enough time, is there?
> OK, WHAT IS NATURAL LANGUAGE PROCESSING
> Just ok, nothing more?
> WHAT IS NLP
> That's for me to know and you to find out!
> I AM GETTING BORED
> Maybe you should get out more.
> WHAT SPORTS DO YOU PLAY?
> What do you like to do for fun?
>
1 (LOCAL) SysOp          Chat With Me! 1.6          0 22:34
G (020999)   Sec(0)=0    Times On= 1    Up:Dn=0:0          HOME=Help  999 22:34
```

📄 A short conversation with Lisa.

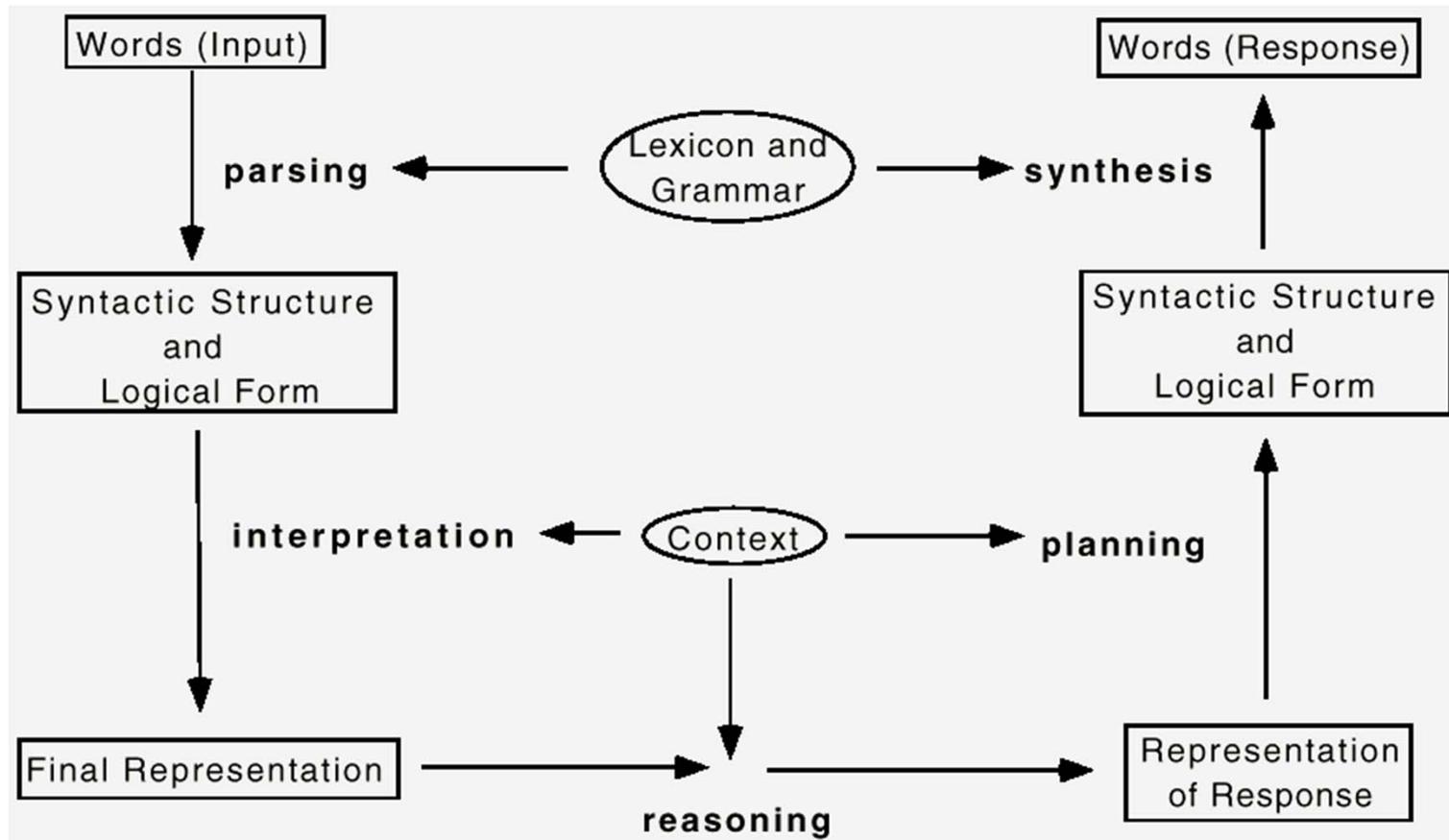
📄 <http://stuff.simplenet.com/files/doorsam/lisa18.zip> ( lisa16.zip is available too)

# Real World NLP Applications

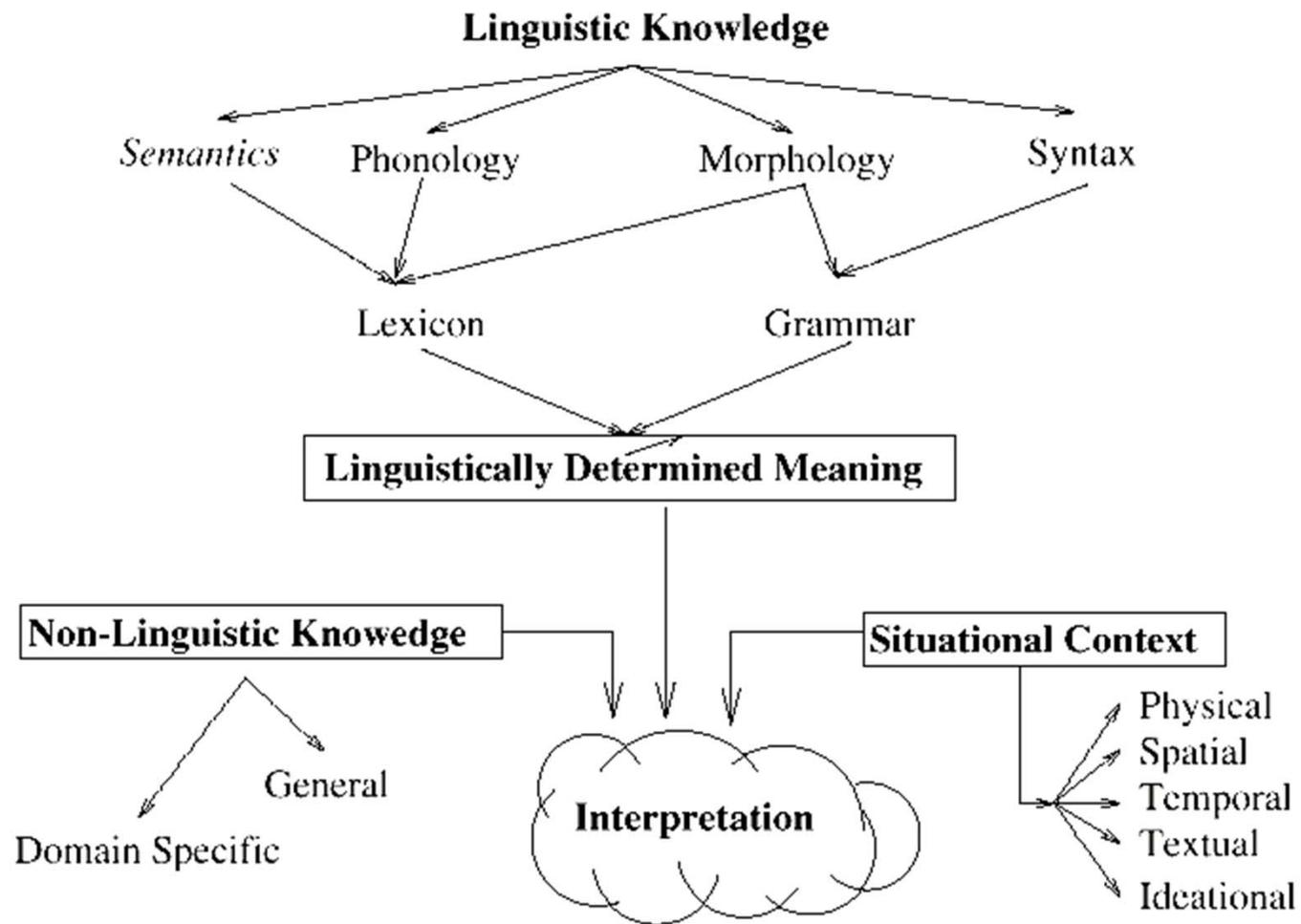
## Grammar Checking Systems: MS Word Grammar Checker



# A Generic NL System Architecture



# Language and Knowledge



# Five Processing Stages in a NLP System



- 📄 Phonological Analysis
- 📄 Morphological Analysis
- 📄 Syntactic Analysis
- 📄 Semantic Analysis
- 📄 Pragmatic Analysis

# Five Processing Stages in a NLP System



## (1) Phonological Analysis

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📄 **Phonetics:** deals with the **physical building blocks** of a language sound system.

eg. sounds of 'k', 't' and 'e' in 'kite'

📄 **Phonology:** **organisation** of **speech sounds** within a language.

eg. (1) different 'k' sounds in 'kite' vs 'coat'

(2) different 't' and 'p' sounds in 'top' vs 'pot'

# Five Processing Stages in a NLP System

## (2) Morphological Analysis



- 📄 **Morphology** is the **structure** of **words**.
- 📄 It is concerned with **inflection**<sup>1</sup>.
- 📄 It is also concerned with **derivation of new words** from existing ones, eg. lighthouse (formed from light & house).
- 📄 In NLP, **words** are also known as **lexicon items** and a **set of words** form a **lexicon**.

<sup>1</sup> The various forms of the same basic word. eg. run-ran, dog-dogs, etc.

# Five Processing Stages in a NLP System

## (2) Morphological Analysis: Why is it important?



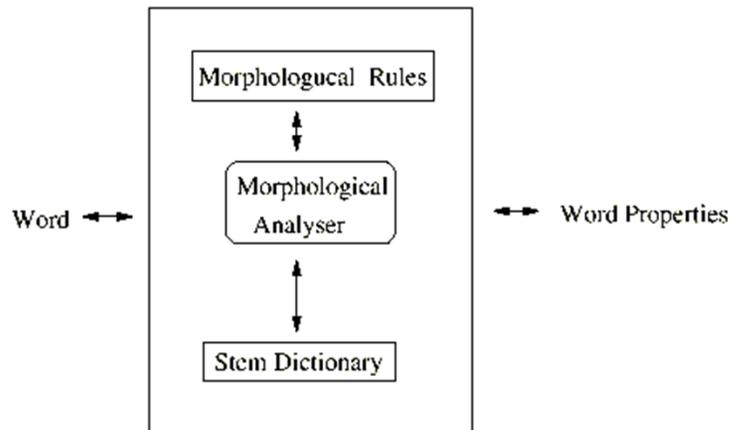
- ☞ Any NL analysis system needs a **lexicon** {a module that tells what words there are and what properties they have.
- ☞ **Simplest model** is a full form dictionary that **lists every word explicitly**.
- ☞ Simply expanding the dictionary fails to take **advantages of the regularities**.
- ☞ **No dictionary** contains all the words one is likely to encounter in real input.
  - Languages with highly productive morphology (e.g. Finnish, where a verb can have many thousands of forms.)
  - Noun Compounding

# Five Processing Stages in a NLP System

## (2) Morphological Analysis: The Lexicon



☞ The black box behaviour of the lexicon is to **relate words to different kinds of information**, as shown by the outer square.



☞ Full form lexicon.

☞ Lexicon with morphological analysis.

☞ The lexicon is a repository of all the exceptions in the language.

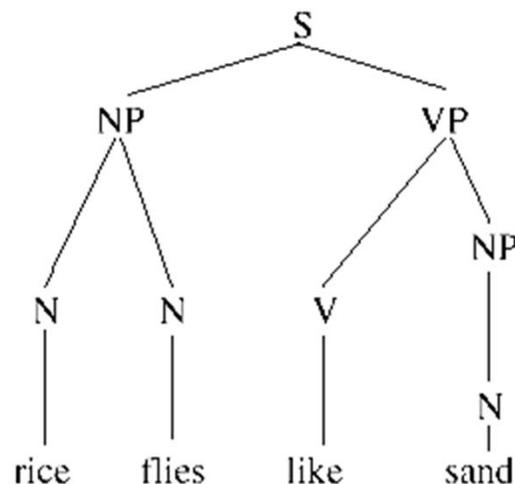
☞ A **lexicon** is also as the **dictionary**

# Five Processing Stages in a NLP System

## (3) Syntactic Analysis



- ☞ **Syntactic analysis** is concerned with the **construction of sentences**.
- ☞ **Syntactic structure** indicates **how the words are related** to each other.



- ☞ **Syntax tree** is assigned by a **grammar** and a **lexicon**.
- ☞ **Lexicon** indicates **syntactic category of words**.
- ☞ **Grammar** (typically Context Free Grammar) specifies **legitimate concatenations of constituents**.

# Five Processing Stages in a NLP System

## (4) Semantic Analysis



☞ **Semantic analysis** is concerned with the **meaning of the language**.

☞ This stage uses the meanings of the word to **extend** and perhaps **disambiguate the result** returned by the **syntactic parse**.

☞ The first step in any semantic processing system is to **look up the individual words in a dictionary** (or lexicon) and **extract** their meanings.

☞ Unfortunately, **many words have several meanings**, for example, the word ‘diamond’ might have the following set of meanings:

- (1) a geometrical shape with four equal sides.
- (2) a baseball field
- (3) an extremely hard and valuable gemstone

☞ **To select the correct meaning** for the word ‘diamond’ in the sentence Joan saw Susan’s diamond shimmering from across the room.

It is necessary to know that neither geometrical shapes nor baseball fields shimmer, whereas gemstones do (process of **elimination**).

# Five Processing Stages in a NLP System



## (4) Semantic Analysis (cont)

- ☞ The **process of determining the correct meaning** of an individual word is call *word sense disambiguation* or *lexical disambiguation*.
- ☞ It is done by **associating**, with each word in the lexicon, information about the **contexts** in which each of the word's senses may appear.
- ☞ Each of the words in a sentence can serve as **part of the context** in which the meanings of the other words must be determined.  
eg. The **baseball field** interpretation of 'diamond' could be marked as a **LOCATION**. Then the meaning of 'diamond' in the sentences "I'll meet you at the diamond" could easily be determined if the fact *at* requires a **TIME** or a **LOCATION** as its **object were recorded as part of the lexical entry for at**.

# Five Processing Stages in a NLP System

## (4) Semantic Analysis (cont)



Other useful **semantic markers** are

- PHYSICAL-OBJECT
- ANIMATE-OBJECT
- ABSTRACT-OBJECT

Using these markers, the correct meaning of ‘diamond’ in the sentence “I dropped my diamond” can be computed.

As part of the lexical entry, the verb ‘drop’ will specify that its object must be a PHYSICAL-OBJECT.

**Unfortunately**, to solve lexical disambiguation problem complete, it becomes **necessary to introduce more and more finely grained semantic markers**.

# Five Processing Stages in a NLP System



## (4) Semantic Analysis (cont)

- ☞ Finally, we have to **process the text at sentence level**. There are **four approaches** to this.
- ☞ First, **semantic grammars** which combine **syntactic, semantic and pragmatic knowledge** into a single set of rules in the form of a grammar.
- ☞ **Second, case grammar** in which the **structure that is built by the parser** contains some **semantic information**, although further interpretation may also be necessary.
- ☞ **Third, conceptual parsing** in which **syntactic and semantic knowledge are combined** into a single interpretation system that is driven by the semantic knowledge.
- ☞ **Lastly, approximately compositional semantic interpretation**, in which **semantic processing** is applied to the result of performing a **syntactic parse**.
- ☞ For details on each method, refer to Rich & Knight AI book, pg 400-414

# Five Processing Stages in a NLP System

## (5) Pragmatic Analysis



- ☞ This is an **additional stage** of analysis concerned with the **pragmatic use of the language**.
- ☞ This is important in the understanding of **texts** and **dialogues**.
- ☞ There are many **important relationships** that may hold between **phrases** and **parts of their discourse context**, as outlined below.
- ☞ Identical entities. Consider
  - Bill had a red balloon.
  - John wanted it.The word 'it' should be identified as referring to the red balloon. References such as this are call *anaphoric* or *anaphora*.

# Five Processing Stages in a NLP System

## (5) Pragmatic Analysis (cont)



### **Parts of entities.** Consider the text

- Tracy opened the book she just bought.
- The title page was torn.

The phrase 'the title page' should be recognized as being part of the book that was just bought.

### **Parts of action.** Consider the text

- Lynn went on a business trip to New York.
- She left on an early morning flight.

Taking a flight should be recognized as part of going on a trip.

### **Entities involving in actions.** Consider the text

- Her house was broken into last week.
- They took the TV and the stereo.

The pronoun 'they' should be recognized as referring to the burglars who broke into the house.

# Five Processing Stages in a NLP System

## (5) Pragmatic Analysis (cont)



### **Elements of sets.** Consider the text

- The stickers we have in stocks are stars, the moons, item and a flag.
- I'll take two moons.

The moons in the 2nd sentences should be understood to be some of the moons mentioned in the 1st sentence.

Notice that to understand the 2nd sentence at all requires that we use the context of the first sentence to establish that the word 'moons' means moon stickers.

### **Names of individuals.** Consider the text

- Dan went to the movies.

Dan should be understood to be some person named Dan. Although there are many, the speaker had one particular one in mind and the discourse context should tell us which.

# Five Processing Stages in a NLP System

## (5) Pragmatic Analysis (cont)



☞ **Causal chains.** Consider the text

- There was a big snow storm yesterday.
- The schools were closed today.

The snow should be recognized as the reason that the schools were closed.

☞ **Planning sequences.** Consider the text

- Margaret wanted a new car.
- She decided to get a job.

Sally's sudden interest in a job should be recognized as arising out of her desire for a new car and thus for the money to buy one.

☞ **Illocutionary<sup>1</sup> force.** Consider the sentence

- It sure is cold in here.

In many circumstances, this sentence should be recognized as having, as its intended effect, that the hearer should do something like close the window or turn up the thermostat.

<sup>1</sup> relating to or being the **communicative effect** (as commanding or requesting) of an utterance <"There's a snake under you" may have the illocutionary force of a warning>

# Five Processing Stages in a NLP System

## (5) Pragmatic Analysis (cont)



📄 **Implicit presupposition.** Consider the query

- Did Adam fail CS310?

The speaker's presupposition, including the fact that CS310 is a valid course, that Adam is a student, and that Adam took CS310, should be recognized so that if any of them is not satisfied, the speaker can be informed.

📄 In order to be able to recognize these kind of relationships among sentences, a **great deal of knowledge about the world** being discussed is required.

📄 Programs that do **multiple-sentence understanding** rely either on **large knowledge bases** or on **strong constraints on the domain of discourse** so that only a limited knowledge based is necessary.

# Class Activity: Real-world Paper Reading

Paper 1. “Intelligent Text Processing, and Intelligent Tradecraft”



- Introduction
- Paradigm Shift
- Patent Searching
- Competitive Intelligence
- Intelligence Tradecraft and Visualization
- Automated Technology Trend Spotting
- Intelligent Agents
- Breaking the Language Barrier
- Never Possible Before

# Class Activity: Real-world Paper Reading

Paper 2. “Comparing DIALOG, TARGET, and DR-LINK”



 Introduction

 Three Search Systems

 NLP vs Boolean

 Changing Perspectives

 Implications

# Class Activity: Real-world Paper Reading

Paper 3. “Text Mining Technology: Turning Information into Knowledge”



## 📄 Mining Text

## 📄 Text Analysis Functions

Language Identification, Feature Extraction, Clustering, Categorization, Text Search Functions, Text Search Engine

## 📄 Scenarios

## 📄 A Portfolio of Technology

Clustering and visualization applications, Prompt Query Refinement, Lexical Navigation, Advanced Feature Extraction, Feature Extraction for non-English language, Text Classification Technologies

# What's in Store for Lecture 11



📄 Natural Language Processing II

📄 Context Free Grammar

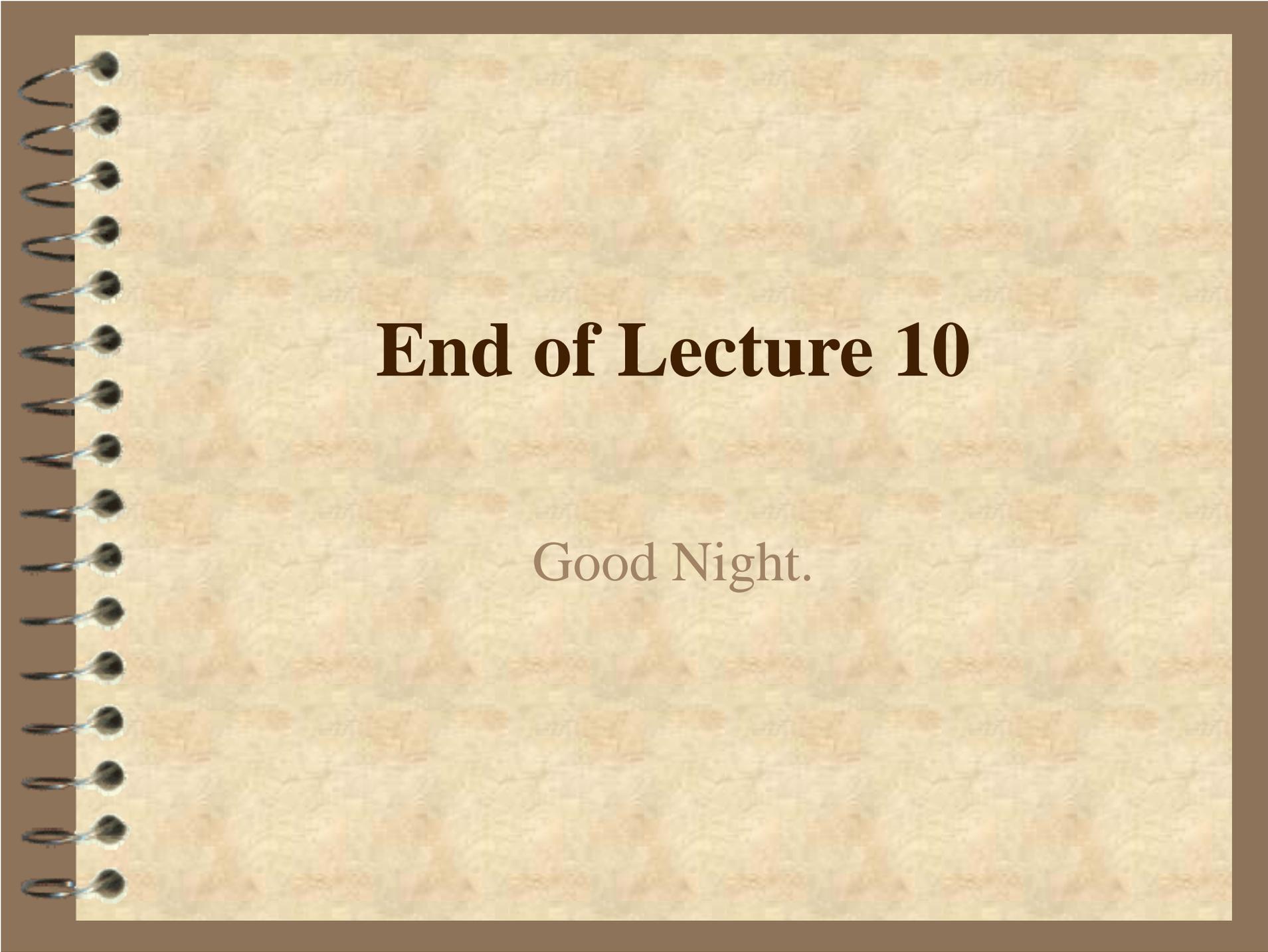
📄 Chomsky's Grammar Hierarchy

📄 Semantics and  $\lambda$ -calculus

# Students' Mini Research Presentation by Group E

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A spiral-bound notebook with a light brown, textured cover and a dark brown border. The spiral binding is on the left side. The text is centered on the page.

**End of Lecture 10**

Good Night.